Recent advances, remaining challenges, and new approaches toward the development of climate-quality turbulent flux records

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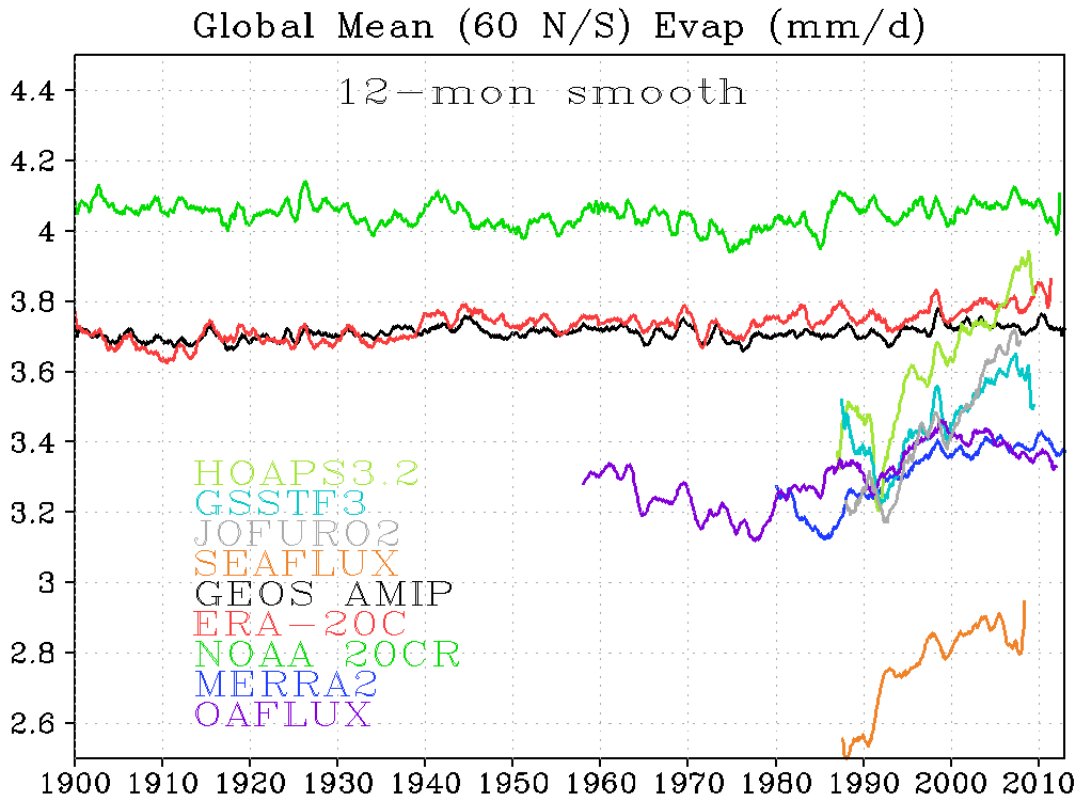
Outline

* CDRs for Turbulent Fluxes
* Current Challenges
* Opportunities for Improvements
* Summary

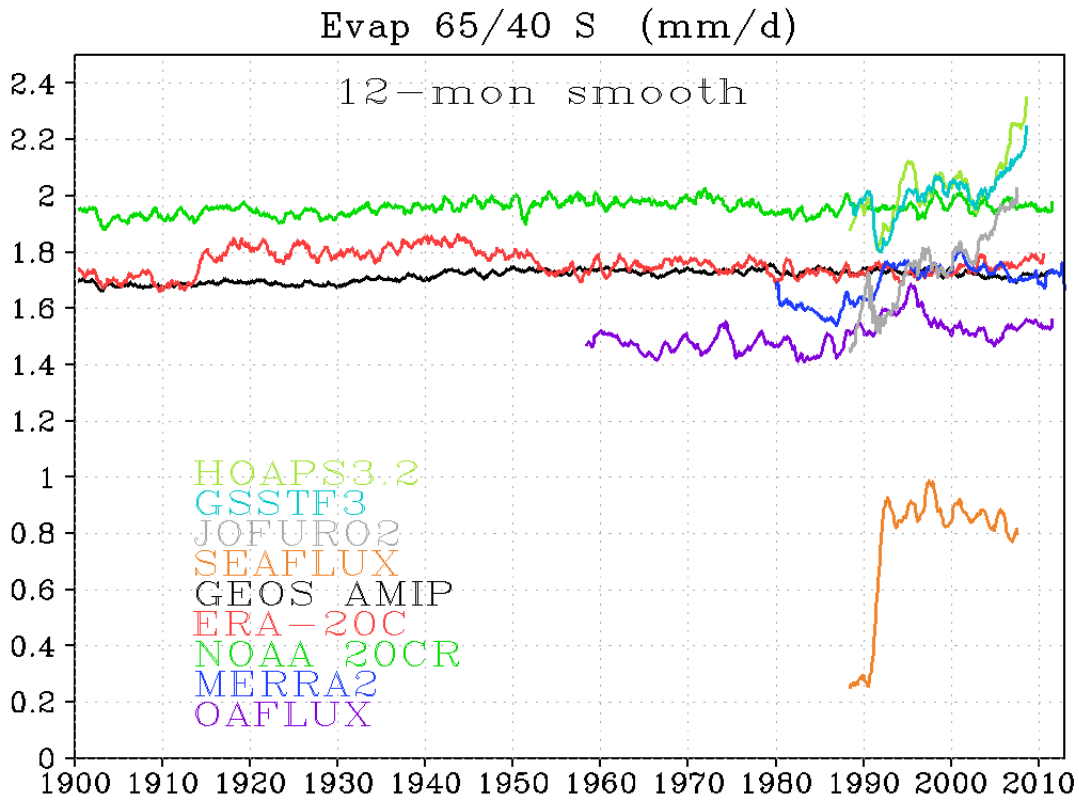
Turbulent Flux Products for "Climate-Quality" Records

* Climate Data Records - "*a time series of measurements of sufficient **length, consistency** and **continuity** to determine climate variability and change.*"
  * Terminology for remote sensing, but in a wider sense may include satellite-era reanalyses, reduced-observing system (RedObs) reanalyses (Earth System Data Records –ESDRs)
* Minimum requirements on ESDR properties will vary based on context of end-users
  * Length – CMIP5/Modelers likely require >>30+ years of data to examine decadal climate variability,
  * Precision – Varies strongly based on spatial/temporal scales of variability

Assessing current landscape of turbulent flux products (Global)



Assessing current landscape of turbulent flux products (Southern Ocean)



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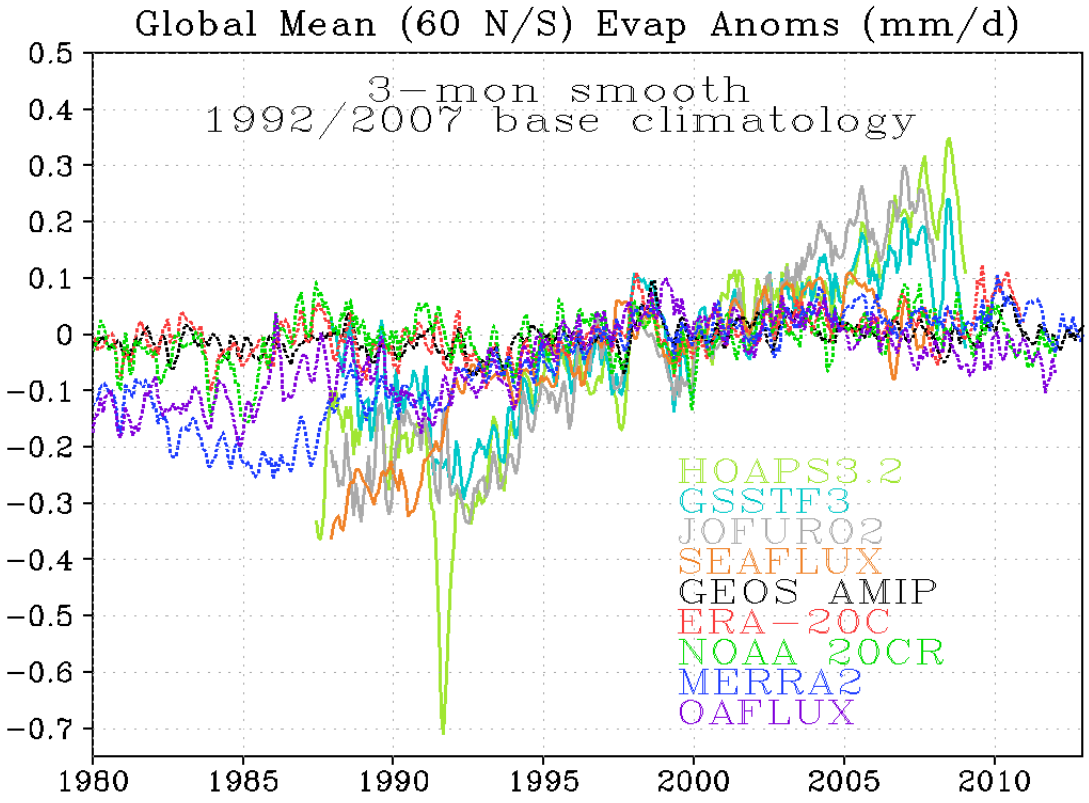

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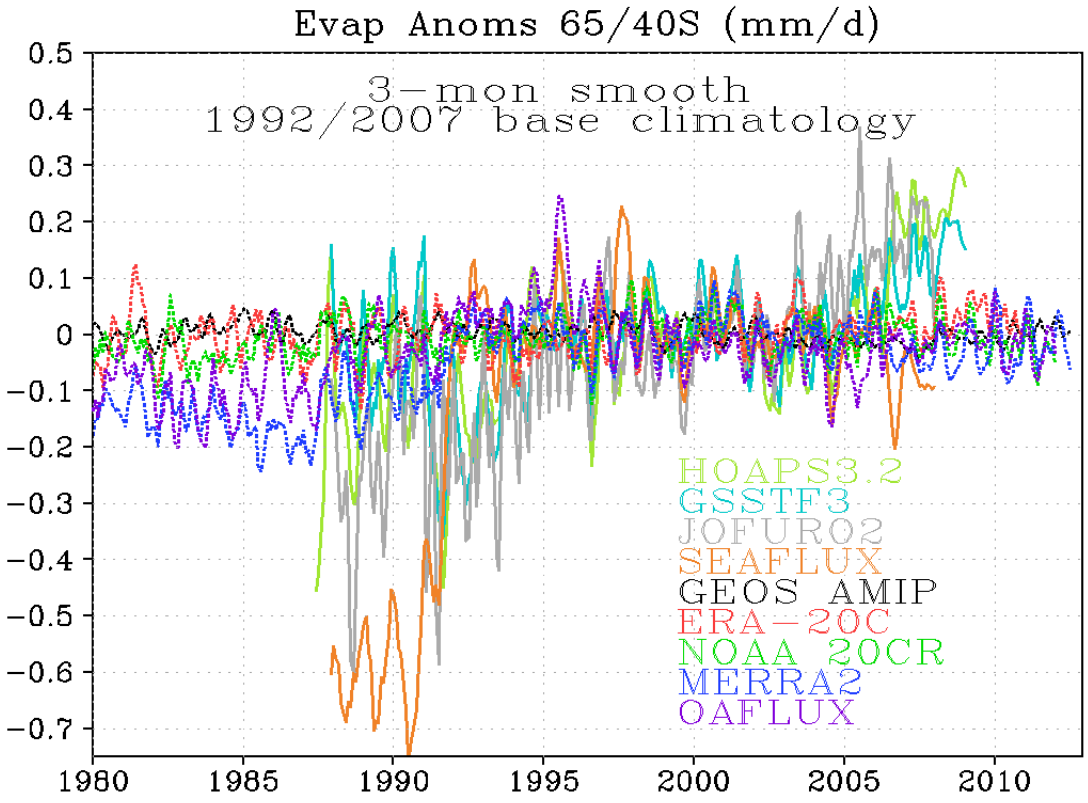
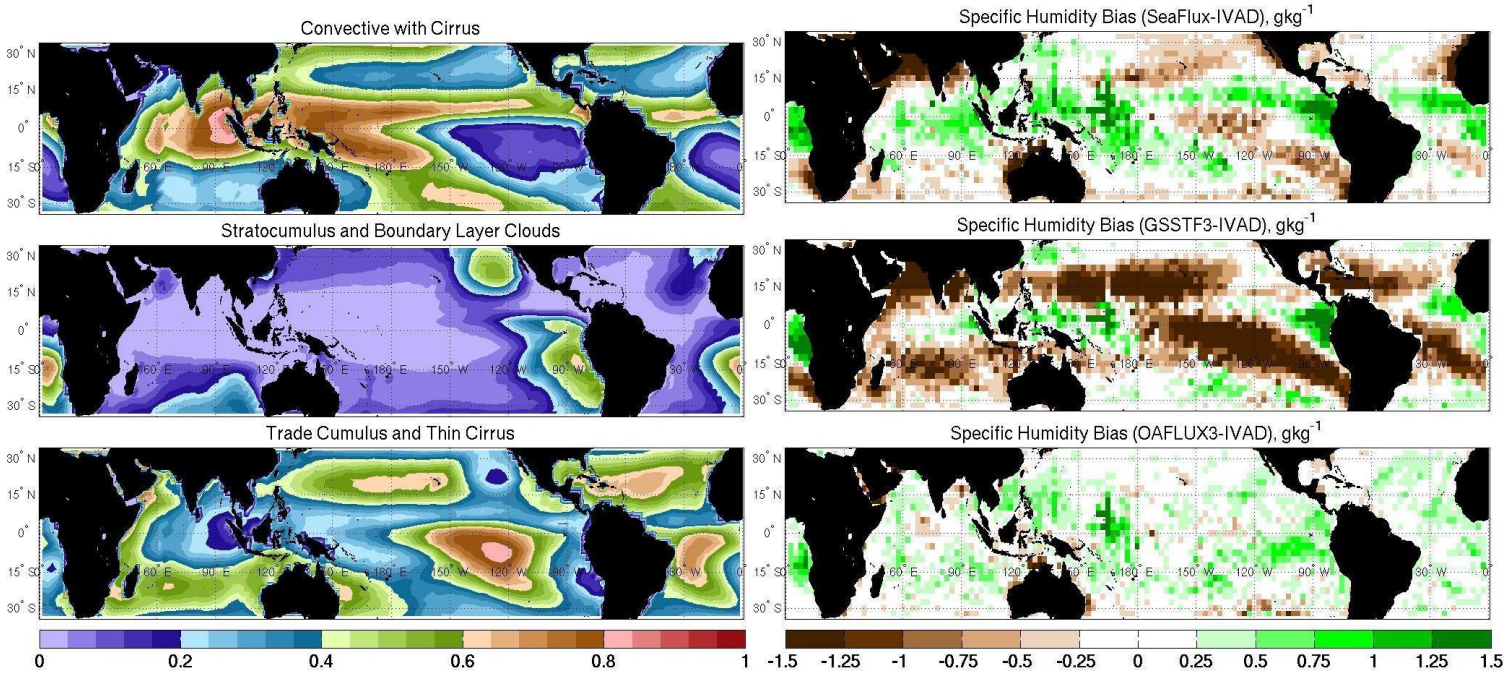


Sources of uncertainty – "Physics"

Remote Sensing

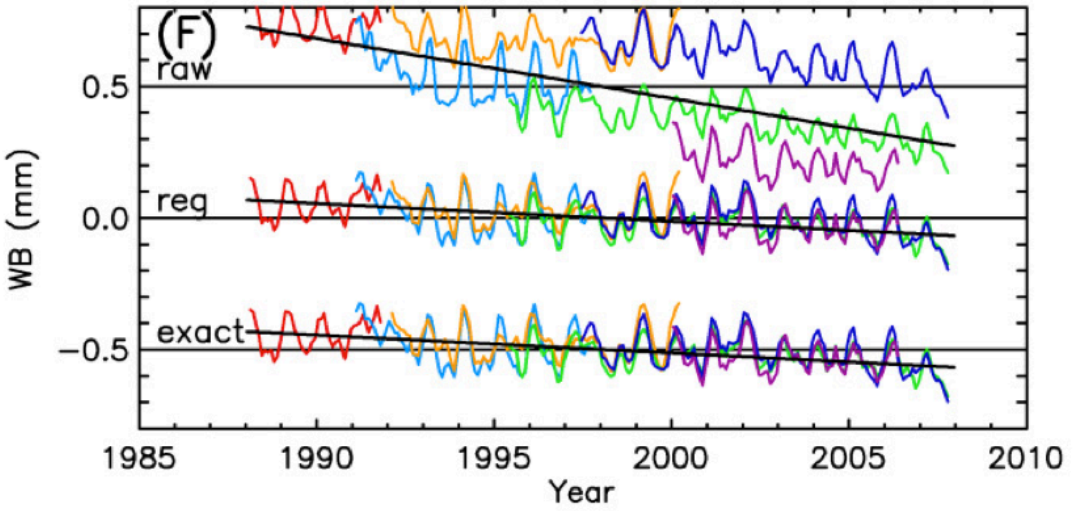
* Retrievals of near-surface variables
  * Near-surface humidity and air temperature retrievals show strong regime-dependent conditional biases
  * Retrievals show significant uncertainty in regions of clouds and decoupled boundary layers – prevalent in Southern Ocean



Sources of uncertainty – Observing System

Remote Sensing

* Currently very little direct information on T/Q within the boundary layer – AIRS provides highest vertical resolution but can't perform in cloudy conditions
* Sampling changes dramatically over the "satellite-era," particularly with respect to passive microwave observations



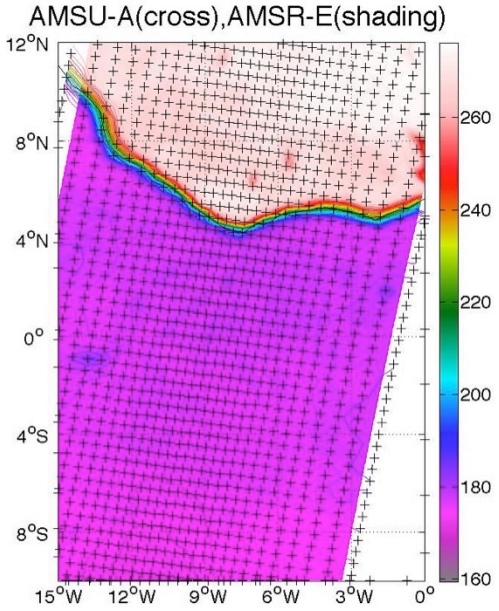
(from Hilburn and Shie 2011)

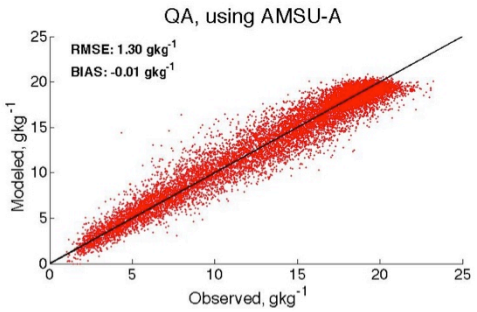
* Sensors must be intercalibrated AND take into account Earth Incidence Angle variations or "artificial" variability may result

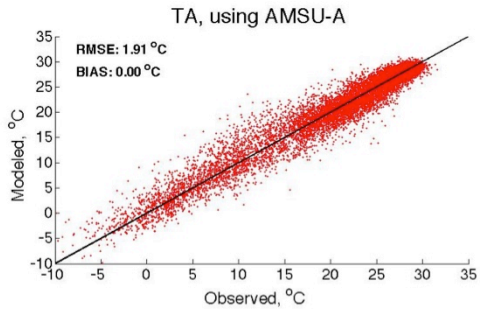
New Opportunities - Retrievals

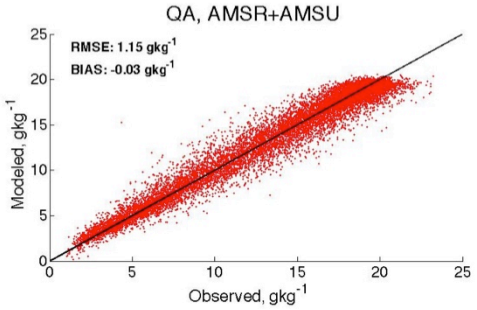
* Incorporate more direct information from available sensors
  * "Data Fusion" – Window + Sounding channels
* Examples:
  * SSM/I + AMSU-A
  * AMSR-E + AMSU-A
  * TMI + AMSU-A
  * SSMIS
  * GMI …

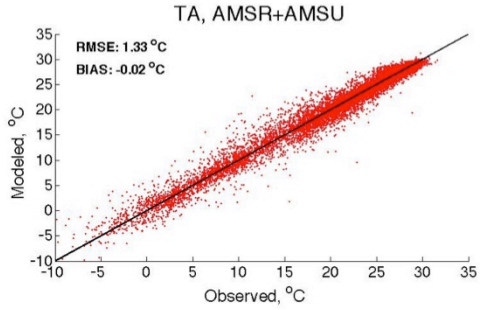
* Potential to reduce RMS errors using multi-sensor retrievals
  * 12% decrease for specific humidity
  * 30% decrease for air temperature
  * Jackson and Wick (2006) found similar reductions
* Does not necessarily address conditional biases due to cloud impacts





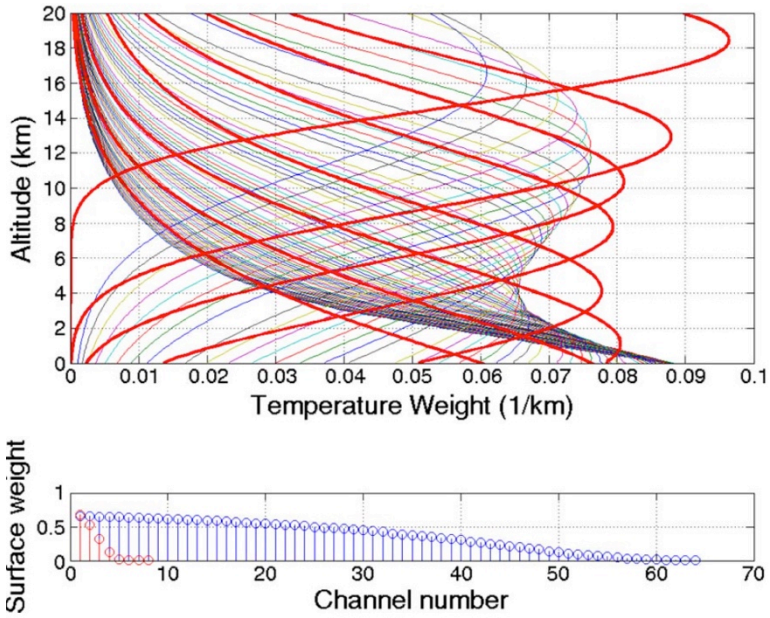


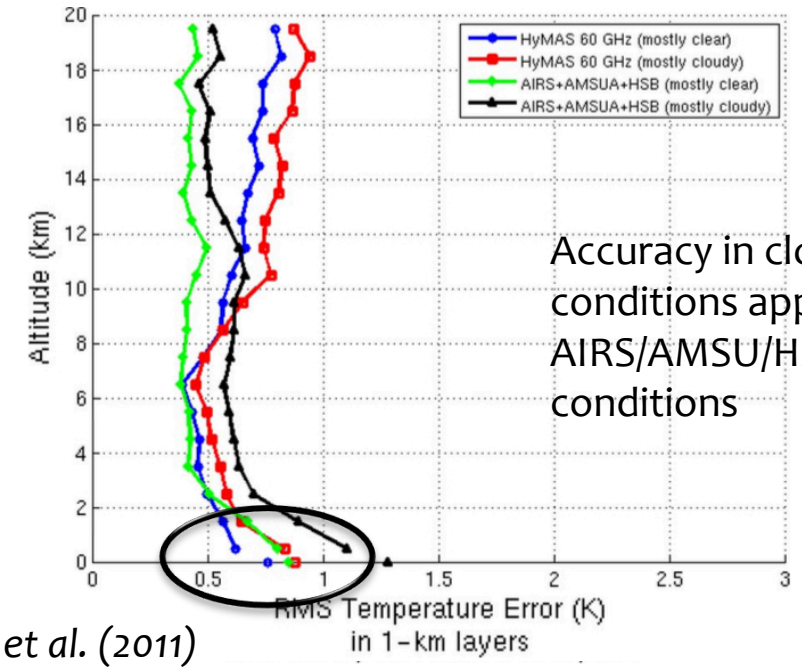




New Opportunities - Retrievals

* Develop new sensors: "Hyperspectral" Microwave Atmospheric Sounding (HyMAS)





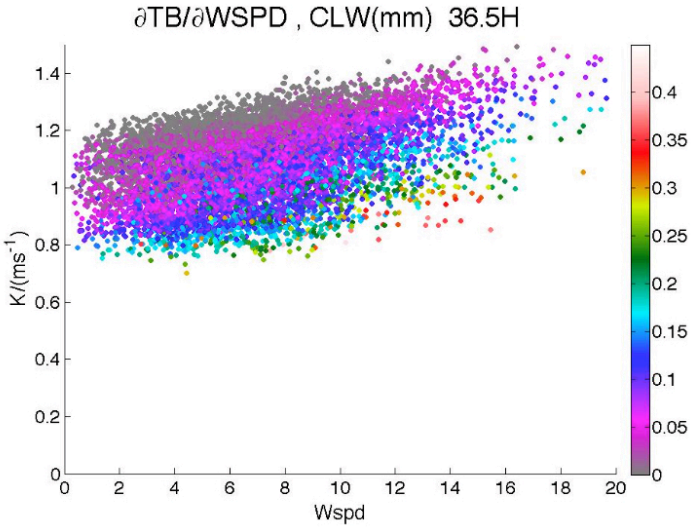
Accuracy in cloudy conditions approaches AIRS/AMSU/HSB in clear conditions

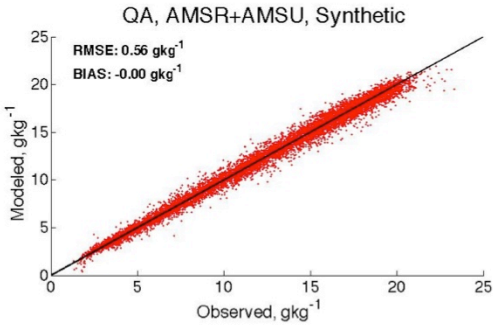
from Blackwell et al. (2011)

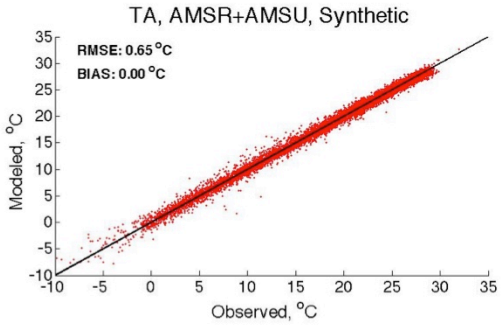
* HyMAS instrument using increased sampling around absorption bands to provide finer vertical weighting structures
* Being developed now as an airborne instrument; potential for future space-based mission

New Opportunities - Retrievals

* Improve handling of cloud-impacts (highly relevant to SOOS)
  * Empirical Cloud Clearing – Retrievals using Clear-Sky brightness temperatures





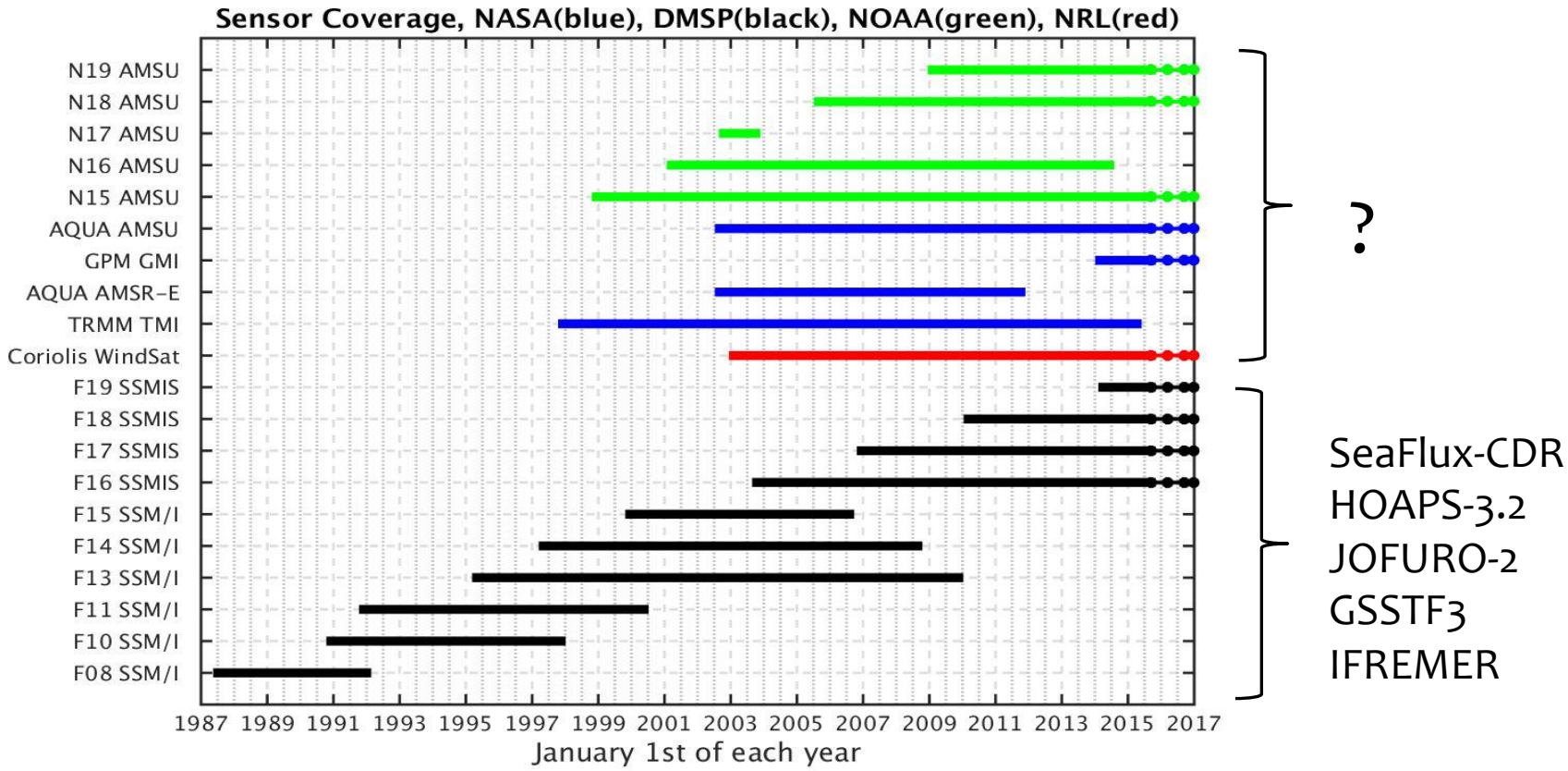


* While true that microwaves "see" through clouds, they can still significantly alter the signal in ways that generate larger errors in our retrievals
* ***If*** we can decompose the observed ,TB_{obs} , into clear-sky and cloudy-residual components, $TB_{obs} = TB_{clr} + TB_{cld}$, then we can attempt retrievals:

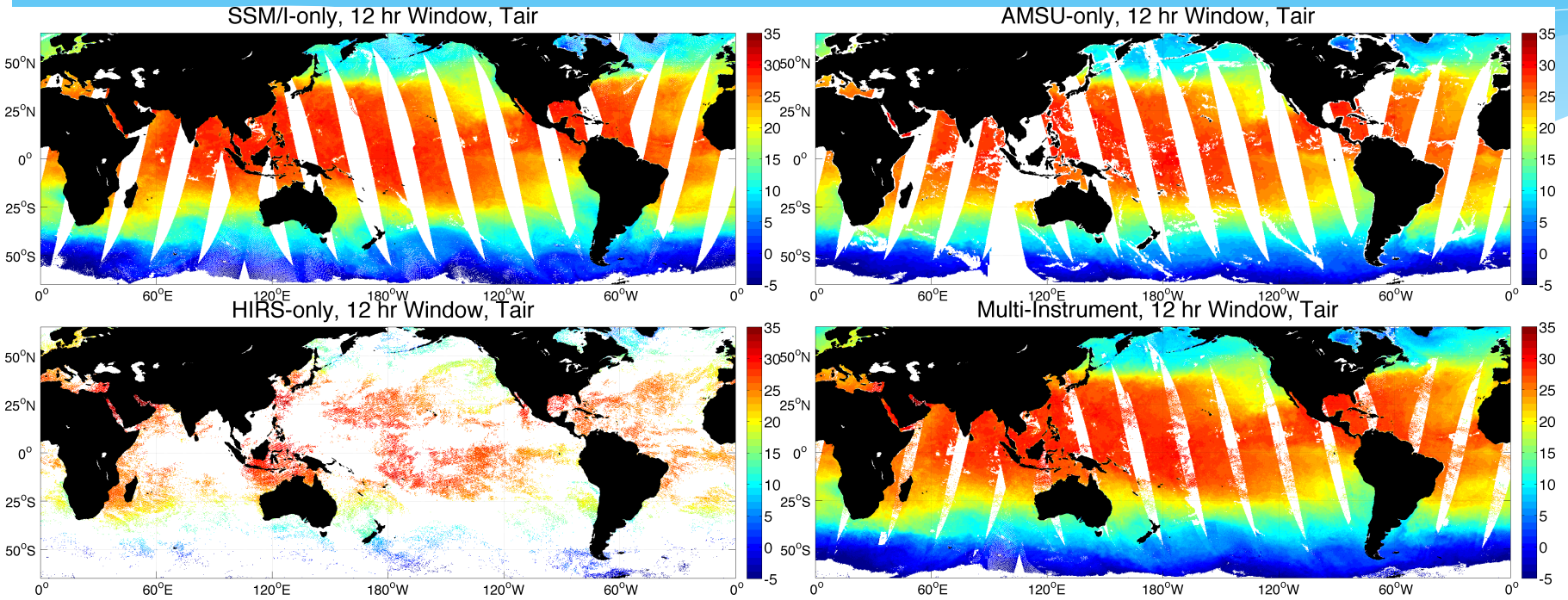
$$\{Qa,Ta,Wspd,SST\} = F^{-1}(TB_{clr})$$

New Opportunities - Observing System

* Use of FCDRs
  * NOAA FCDRs for SSM/I, SSMIS , AMSU-A
  * GPM X-Cal Group – GMI, TMI, AMSR-E
* Improve sampling – SSM/I, SSMIS, AMSU-A, AMSR-E, TMI, GMI, ***AIRS*, HIRS*, Scatterometers****
  * Probably more relevant globally than over Southern Ocean only



New Opportunities – Observing System



* Combining multiple sensors should leaved to improved sub-daily resolution — Not necessarily as large of an impact on monthly-averages (how many samples do you need?)
* The focus here has been on passive microwave, but IR sensors (e.g. HIRS, AIRS) can also provide estimates of near-surface and can be incorporated into future remotely-sensed products

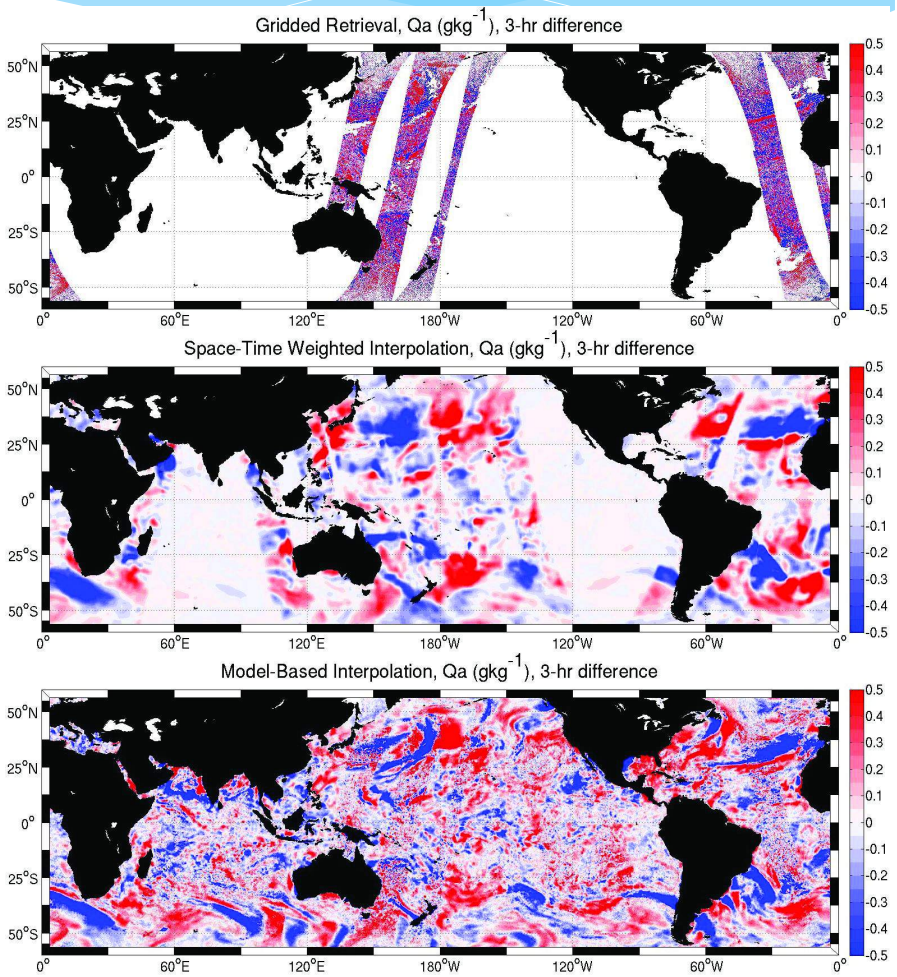
New Opportunities – Observing System

* Model-based interpolation (MOBI)
  * Need to combine remote sensing estimates and handle missing data – due to sampling or inability to perform retrievals (e.g. rain contamination, bad data)
  * Drive model reanalysis directly through observations

(Analysis Equation)

$$X_t = M_t + \Delta_A + (n/N\,\Delta_B - n/N\,\Delta_A)$$

M_t : Reanalysis estimate
S_t : Satellite estimate
Δ_A : $S_A - M_A$
Δ_B : $S_B - M_B$
A : beginning of time interval with observed value
B : end of time interval with observed value
n/N : fractional time along interval between A and B at which X_t is estimated



Summary

* There are multiple challenges at present for the development of accurate, precise, and consistent climate data records of turbulent latent and sensible heat fluxes
* Large conditional/regional biases affect current remote sensing based estimates of near-surface air temperature and humidity, particularly under different cloud regimes
* Changes in the passive microwave observing system can generate anomalous variability in estimated turbulent fluxes
* New advances are being made to address the development of climate-quality turbulent fluxes from remote sensing, including:
  1. Data Fusion
  2. New sensor development
  3. New approaches to handling cloud impacts on microwave TBs
  4. Improved sampling and analysis/blending techniques